MEMO

TO: Energy and Environment Committee

FROM: Ted Harris, Associate Regional Planner, 213-236-1916, harrist@scag.ca.gov

DATE: October 7, 2004

SUBJECT: Children's Health Study

Recommended Action:

Information.

BACKGROUND

The committee will be briefed on the California Air Resources Board (ARB)/University of Southern California (USC) Children's Health Study, which has provided new findings on the effects of air pollution on children's health. This 10-year, $18 million study produced results showing how air pollution reduces children's lung growth and function, impacts respiratory health in asthmatic children, including new asthma cases, and contributes to increased school absences.

California ARB Chairman Dr. Alan Lloyd said, "This study has added greatly to our basic understanding of air pollution's effects on our children's health and reinforced the need to continue our efforts to reduce the pollution affecting millions of children."

The study, conducted by researchers from the University of Southern California (USC), was the nation's first large-scale effort to study the effects of long-term exposure to outdoor air pollution in children, one of our most sensitive populations.

The study followed more than 5500 children at 52 schools in twelve Southern California communities from elementary through high school to track how different outdoor air pollution exposures affect respiratory health. The majority of children enrolled in the program as fourth-graders and were followed through high school.

The major findings of the study were:

- Significant lung function deficits are most closely associated with exposure to nitrogen dioxide, atmospheric acidity, PM 2.5 and PM10. This decreased lung development may have permanent adverse effects in adulthood.
- Children living in high ozone communities, who are especially active, are up to three times more likely to develop asthma.
- Children living near roadways with high traffic experienced an increased risk for having been diagnosed with asthma.
- Short-term exposures to elevated ozone levels are associated with a significant increase in school absences from both upper respiratory illness with symptoms such as runny nose and lower respiratory illnesses such as asthma attacks.

- Children who move to cleaner communities with lower levels of PM have improvements in lung function growth rates. This means that even small reductions in air pollution can have immediate benefits to the long-term respiratory health of children living in polluted communities.
- Bronchitic symptoms are associated with exposure to nitrogen dioxide and the organic carbon fraction of PM2.5 in asthmatic children.
- Children exposed to higher levels of particulate matter, nitrogen dioxide, acid vapor and elemental carbon, had significantly lower lung function at age 18, an age when the lungs are nearly mature and lung function deficits are unlikely to be reversed.

Outdoor pollution monitoring tracked levels of ozone, nitrogen oxide, acid vapor and particulate matter over the 10-year study. In addition, limited indoor pollution measurements were taken at schools and in homes. Each spring, the lung function of each child was tested and annual questionnaires collected information about respiratory symptoms and diseases, physical activity, time spent outdoors, and factors such as parental smoking, and mold and pets in the household.

The 12 communities studied were: Atascadero in San Luis Obispo County; Lompoc and Santa Maria in Santa Barbara County; Lake Arrowhead and Upland in San Bernardino County; Lancaster, Long Beach and San Dimas in Los Angeles County; Lake Elsinore, Mira Loma and Riverside in Riverside County; and, Alpine in San Diego County.

The study has been funded by the California Air Resources Board (ARB) with other support from the U.S. Environmental Protection Agency, South Coast Air Quality Management District and other local air pollution control districts. Although the ARB funding support for the health portion of the study has concluded, the investigators have received a grant from the National Institute of Environmental Health Sciences to continue the program for an additional three years. The ARB will continue to work in collaboration with the CHS investigators through assistance with the monitoring network as they continue with this work.

A final report of the study is posted at (http://www.arb.ca.gov/research/abstracts/94-331.htm), and the Executive Summary is attached.

EPIDEMIOLOGIC INVESTIGATION TO IDENTIFY CHRONIC EFFECTS OF AMBIENT AIR POLLUTANTS IN SOUTHERN CALIFORNIA

Prepared for the California Air Resources Board and the California Environmental Protection Agency
Contract No. 94-331

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Abstract

A prospective study of about 6000 children living in 12 Southern California communities of varying ambient air pollution profiles was initiated in 1993. The primary purpose of the study was to determine whether air pollution causes chronic adverse respiratory health effects. Particulate matter (hourly PM_{10}, two-week-integrated $PM_{2.5}$, and several constituents including elemental and organic carbon, metals, and ions), ozone (O_3), nitrogen dioxide (NO_2), and acid vapor (primarily nitric) were measured in each community during the study period. Health outcomes assessed were annual pulmonary function tests (maximal spirometry), annual questionnaires on respiratory conditions and symptoms, and school absence monitoring. Demographics, housing characteristics, time-activity patterns and exposure to tobacco smoke were also assessed annually by written questionnaire. Study results indicated that children's lung function growth was adversely affected by air pollution, new cases of asthma and asthma exacerbations were associated with ambient air pollution levels, and school absences from acute respiratory illnesses followed rises in ozone levels. We conclude that current levels of ambient air pollution in Southern California are associated with clinically important chronic health effects that have substantial health and economic impacts. These findings indicate the need for cleaner air for our children to breathe.

1. Executive Summary

1.1. Background

Air pollution in Southern California continues to pose significant challenges to regulatory agencies and to health professionals. Several million persons living in the region are exposed to pollution levels that have been associated, in laboratory and field investigations, with acute and sub-acute respiratory effects. When the Children's Health Study (CHS) began in the early 1990s, it was known from laboratory observations that acute exposure to air pollutants produced decrements in pulmonary function, increased prevalence of respiratory symptoms, and respiratory tract inflammation. The paramount CHS research question has been whether *chronic* respiratory disease occurs as a result of breathing polluted ambient air.

In short-term exposure studies of humans in controlled exposure chambers, among common air pollutants, ozone shows the strongest evidence of adverse effects. Numerous laboratory exposure-response studies in human volunteers have shown that lung function losses, respiratory irritant symptoms, and increases in bronchial reactivity result from ozone exposure levels commonly observed in the South Coast Air Basin (SoCAB), either from comparatively brief (~1 hour) exercise at "alert" concentrations of 0.2 ppm and higher or from prolonged exercise at concentrations near the California ambient air quality standard of 0.09 ppm (US Environmental Protection Agency 1986; Folinsbee et al. 1988; Lippmann 1989; Lippmann 1991). Recovery to normal function levels typically takes several hours after ozone exposure ceases. Some effects of short-term exposure persist for more than 24 hours. At the time the study began, similar acute effects had not been seen from other pollutants at the levels encountered in Southern California [nitrogen oxides (NO_x), particulate matter less than 10 microns in diameter (PM_{10}) or acid vapors]. Since the study began, many hundreds of papers have been published demonstrating the relationship between pollutant levels and morbidity and mortality. This literature is well summarized by Brunekreef and Holgate (2002).

Studies of humans conducted in Southern California have suggested the possibility of chronic respiratory effects from air pollution (Detels et al. 1987; Abbey et al. 1991; Sherwin 1991; Sherwin and Richters 1991), but because of population attrition in the Detels studies, reliance on questionnaire data in the Abbey study, and possible confounding in the Sherwin study, conclusions are uncertain. When the Children's Health Study began, essentially no human data on children existed on chronic respiratory effects resulting from specific components of air pollution. The large number of persons in Southern California exposed to air pollution, the existing data on acute effects, and the available air monitoring data have provided a unique opportunity to examine chronic health effects resulting from air pollution in humans. The identification of health effects plus the generation of dose-response data provides regulators with highly valuable information for risk management.

Children were selected as the study population for several reasons: they often spend more time outdoors; they exercise more than adults; they do not smoke (at least the young ones); they do not have hazardous occupations; they are more likely to have spent their entire lives in Southern

California; their growing lungs may be more sensitive to the effects of air pollution and they are accessible in large numbers through schools.

1.2. Methods

Community selection was based on air pollution levels and exposure patterns plus demographic data of a group of census tracts in 86 communities. The basic principle governing the selection of communities was to select a group of communities having widely divergent exposure characteristics. A second principle we followed was that the communities being compared should be similar with respect to potential confounding variables. Following these principles, we selected 12 communities in 6 Southern California counties.

Participating study schools were selected based on: (1) location in a pre-selected community of interest based on air pollution levels and patterns; (2) sufficient population of target-aged children; (3) preponderance of children attending school from the immediate neighborhood; (4) demographic similarity with other potential and participating community school sites; (5) absence of localized air pollution sources such as close proximity to factories or freeways; and (6) proximal location to a fixed-site air monitoring station. The design approach specified child entry into the study at the fourth, seventh, and tenth grades and required the enrollment of at least four schools in each community (two elementary schools, a junior high school, and a senior high school).

Three cohorts were established in 1993; one with about 900 tenth grade students, another with about 900 seventh grade students, and still another with about 1800 fourth grade students. These cohorts are referred to in this report as cohorts A, B, and C. In 1996, about 2,000 additional fourth grade students were enrolled in the study. This cohort is referred to as cohort D. In each case, students who continued to reside in the twelve communities were evaluated annually through high school graduation (twelfth grade). Students in cohort D will graduate from high school in 2004. In this report, we report on data collected through high school graduation on cohorts A, B, and C. We also report on four years of follow-up data on cohort D.

The CHS written questionnaire was composed of several sections: demographics, a medical history, a housing survey, exposure to tobacco smoke, exposure to pets and pests, and a time-activity assessment. An extensive set of questions was asked about the history of respiratory diseases. These included asthma, bronchitis and pneumonia and associated symptoms such as cough, phlegm production and wheezing. The initial questionnaire collected information on the past history of these conditions and symptoms including frequency and time of onset. Asthma questions considered physician diagnosis, severity and medication use. Each annual follow-up questionnaire concentrated on adverse respiratory health experiences during the past year and allowed us to ascertain the incidence of new-onset conditions such as physician-diagnosed asthma and bronchitis.

Lung function testing took place in the spring of 1993 and in each subsequent spring to minimize seasonal confounding with intercurrent summer or winter acute air pollution episodes. The subjects were asked to perform at least 3 satisfactory maximal expiratory maneuvers. A maximum of 7 efforts were attempted. Six testing units (spirometers), operated by trained lung function technicians, were dispatched to conduct field-testing in a given community. Each

community was visited at least twice (at least one month apart) with half the participating subjects being tested each visit. The annual follow-up pulmonary function tests were planned to achieve as close to a 12-month interval between testing as possible. Heights and weights of the subjects were measured at the time of each lung testing.

The absence monitoring activity was designed to collect data to determine the frequency and severity of respiratory illnesses in relation to concurrent ambient air pollution levels and to compare respiratory disease patterns between communities and by exposure to various pollutants. Because schools were required by the State Department of Education to keep data on absences in order to receive capitation funding for students for most of the effective study period, there was motivation for schools to collect accurate data. We used documented school absences to trigger an investigation of the reason for the absence. This involved phoning the student's home to interview the parent or guardian. By this approach we were able to classify whether the illness was respiratory. We also asked whether the child had seen a doctor related to the reported absence, and if so, the doctor's diagnosis was noted. We asked about use of medications since this might provide an indication of the severity of the illness.

Monitoring stations were established in each of the twelve communities. This was accomplished by augmenting seven existing regional air monitoring stations and creating five new stations in late 1993 and early 1994. Continuous hourly measurements of ozone (O_3), nitrogen dioxide (NO_2), and PM_{10} were made at each station. Integrated measurements of particulate matter less than 2.5 microns in diameter ($PM_{2.5}$) mass, PM chemical constituents, and acid vapors were made using a multi-legged two-week sampler (TWS) designed for the study (Hering et al. 1994; Lurmann et al. 1994). The PM chemical constituents included $PM_{2.5}$ sulfate, nitrate, and ammonium and PM_{10} elemental carbon (EC) and organic carbon (OC). The main carbon sampling leg did not have a size-selective inlet; however, testing indicated the particle size-cut was approximately 10 μm. A second carbon sampling leg was implemented in 2001 with a 2.2 μm size cut for comparison purposes. Throughout this report, references to $PM_{2.5}$ EC and OC concentrations refer to concentrations derived from the ~PM_{10} EC and OC measurements by application of suitable adjustment factors. The TWS also collected samples for determination of concentrations of nitric acid, hydrochloric acid, formic acid, and acetic acid (collectively described in this report as acid vapor). These measurements were made throughout the study period, 1994-2001. Additional measurements of carbon monoxide (CO), particle number (PN), $PM_{2.2}$ EC, $PM_{2.2}$ OC, and $PM_{2.2}$ elements by x-ray fluorescence (XRF) were implemented in most communities in 2000 and 2001. Also in 2001, the measured nitric oxide (NO) concentrations were retrospectively added to the database. Hourly temperature and relative humidity were measured at some of the CHS air monitoring stations for some of the years to complement the air quality data. These data were supplemented with meteorological data collected at locations near the CHS communities.

Information on usual time-activity profiles and household characteristics were collected annually for all CHS participants. These variables were used directly in health models as potential confounders or effect modifiers, and they were used indirectly in models of microenvironmental concentrations of O_3, PM_{10}, $PM_{2.5}$, and NO_2 in homes, schools, and vehicles to derive estimates of individual exposures to these pollutants. Traffic density data on freeways and major arterial roadways were combined with meteorological data, using line-source dispersion models, to

predict local pollution concentrations at all CHS participants' homes and all schools. These model-based predictions were supplemented by measurements of NO_2 concentrations during two 2-week periods in 287 homes across the 12 CHS communities.

Multi-level random effects models were used for the statistical analysis of the health outcome data in relation to air pollution and other risk factors. This approach provides a unified and valid way to assess associations at three levels of comparison: over years, between individuals, and between communities.

1.3. Results

Our findings demonstrated an association between breathing polluted air in Southern California and significant chronic deficits in lung function among adolescent children. We observed air pollution effects on lung function level at study entry (youngest cohort, age 10yrs), on 4-year lung function growth (age 10-14 years) in two independent cohorts, on 8-year lung function growth (age 10-18 years) in the original fourth grade cohort, and on the maximum rate of lung function growth during adolescence (over the study period). Air pollution exposure over the 8-year (from fourth grade to twelfth grade) study period was also linked to clinically significant deficits [forced expiratory volume in one second (FEV_1) below 80% predicted] in lung function at age 18 years. We found that there were three to five times more children with clinically significant deficits in lung function living in communities with high outdoor air pollution levels compared to communities with low pollution levels. In a subset of children who moved away from their original study community, we observed consistent associations of changes in lung function growth rates with corresponding changes in ambient air pollution exposure between their former and current communities of residence. The pollutants most closely associated with lung function deficits were NO_2, acids (either inorganic, organic, or a combination of the four acids monitored), PM_{10}, and $PM_{2.5}$. Several constituents of $PM_{2.5}$, including EC, nitrate, and ammonium, also showed associations with lung function growth. However, the inter-correlation among PM pollutants, and their high correlations with NO_2 and acid, limited our ability to distinguish the independent effects of any one of these pollutants.

Our findings demonstrated effects of air pollution on both new onset asthma and asthma exacerbations. Prior to the performance of the CHS, the prevailing scientific view was that air pollution made existing asthma worse but that it did not *cause* new cases to develop. Study data showed that new cases of asthma are much more likely to occur in high ozone communities, especially among those children who exercise regularly and at elevated levels. Additionally, our analyses regarding exposure to traffic-related air pollution have found associations between proximity to high traffic density (a marker for pollutant exposure) and increased risks for prevalent asthma among children.

We have demonstrated that air pollution is related to bronchitic symptoms and that asthmatics are more likely to be affected than non-asthmatics. Evaluation of the longitudinal data implicated NO_2 and organic carbon as being responsible for the observed effects.

Our results showed that short-term changes in O_3, but not NO_2 or PM_{10}, were associated with a substantial increase in school absences from both upper and lower respiratory illness. Absences were significantly increased 2 to 3 days after exposure and reached a peak on day 5 after

exposure. Because exposures at the levels observed in this study are common, the increase in school absenteeism from respiratory illnesses associated with relatively modest day-to day changes in O_3 concentration documents an important adverse impact of O_3 on children's health and well-being.

Our data also demonstrate an association between ozone levels and birth weight of children. High ozone levels during the second or third trimester of pregnancy are associated with lower birth weight. Other manuscripts resulting from this study have demonstrated the important health effects associated with maternal smoking, environmental tobacco smoke, genetics, obesity, and dietary factors.

1.4. Conclusions

Our main conclusion is that current levels of air pollution in Southern California are associated with several serious health effects that are costly to children's health and to the state. Lung function was found to be consistently associated with a package of highly correlated pollutants that include particulates, NO_2, and acids, but not ozone. This impact of vehicle-related pollution on children's lung function is likely to have life-long adverse health sequelae. The demonstration of strong evidence linking exposure to new cases of asthma (the most common chronic disease of childhood) to ozone is another striking association. It is also important to note that most of these associations extend to pollution levels below current ambient air standards and may exert significant health effects. Taken as a whole, the results from the Children's Health Study should provide scientific support for aggressive and accelerated efforts to achieve clean air for our children to breathe.